Safety Critical Structures Data Package

Fluids and Combustion Facility
Combustion Integrated Rack

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Preliminary
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Date	**Signature**
12/21/00	*/s/ Robert H. Van Niel*

Prepared For:
National Aeronautics and Space Administration
John H. Glenn Research Center
Microgravity Science Division
Cleveland, Ohio 44135

Prepared By:
Federal Data Corporation
Under Contract NAS3-99155
2001 Aerospace Parkway
Brook Park, Ohio 44142

PREFACE

The National Aeronautics and Space Administration (NASA) is developing a modular, multi-user experimentation facility for conducting fluid physics and combustion science experiments in the microgravity environment of the International Space Station (ISS). This facility, called the Fluids and Combustion Facility (FCF), consists of three test platforms: the Fluids Integrated Rack (FIR), the Combustion Integrated Rack (CIR), and the Shared Accommodations Rack (SAR). This document presents a summary of the structural analysis conducted to support the CIR delta PDR. Earlier structural analysis conducted to support the CIR PDR is documented in CIR-RPT-0009, CIR Design Analysis Report.

At the time of writing, some of the required analyses are incomplete or yet to be started. This document will be revised when the full set of analyses are complete.

**SAFETY CRITICAL STRUCTURES DATA PACKAGE
FOR THE
FLUIDS AND COMBUSTION FACILITY
COMBUSTION INTEGRATED RACK**

Prepared By: *<u>/s/ Timothy L. Sullivan</u>* **Date:** *<u>12/20/00</u>*
Timothy L. Sullivan
Structural Analysis Lead, FCF
Common Systems
Analex Corporation

Reviewed By: *<u>/s/ Will Quinn</u>* **Date:** *<u>12/20/00</u>*
Will Quinn
Manager, Product Assurance
Hernandez Engineering

Approved By: *<u>/s/ Jon C. Wetherholt</u>* **Date:** *<u>12/20/00</u>*
Jon Wetherholt
Manager, Systems Engineering
Analex Corporation

Approved By: *<u>/s/ Andrew M. Peddie</u>* **Date:** *<u>12/21/00</u>*
Andrew M. Peddie
FCF Deputy Director
Federal Data Corporation

Approved By: *<u>/s/ Christopher J. Pestak</u>* **Date:** *<u>12/20/00</u>*
Christopher J. Pestak
FCF Director
Analex Corporation

REVISION PAGE
CIR SAFETY CRITICAL STRUCTURES DATA PACKAGE

Revision	Date	Description of Change or ECO's/ECP's Incorporated	Verification and Date
Draft	10/02/00	Initial	10/23/00
Preliminary, Rev. 1	12/20/00	Add material properties section, deployment slides section, combustion chamber section, additional figures and additional analysis results	12/21/00

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1.0 INTRODUCTION

1.1 Purpose.

The purpose of this document is to provide a summary of the analyses conducted to assure that all safety critical structures in the Combustion Integrated Rack (CIR) are safe to fly. It covers the development of finite element models (FEMs), derivation of design loads, and fracture, fatigue and stress analyses conducted to show positive margins of safety for all structure in the primary load path as well as for pressurized systems.

The analyses conducted are based on the interface requirements of SSP 57000 and the guidelines and requirements of SSP 52005. The structural design and verification criteria used in the development of FCF hardware are documented in FCF-PLN-0053.

1.2 Scope.

Included in this document is analysis of hardware unique to the CIR as well as hardware that are common to each FCF rack. The following is a list of the FCF subsystems that are included:

- CIR Optics Bench assembly
- Optics Bench Deployment Slides
- Air Thermal Control Unit (ATCU) assembly
- Input/Output Processor (IOP) assembly
- Rack Closure Door (RCD) assembly
- Electric Power Control Unit (EPCU) rails and brackets
- Water Thermal Control System (WTCS)
- Gas Interface System (GIS)
- Fire Detection and Suppression System (FDSS) probe

Included with each subsystem are the brackets used to attach it to the International Standard Payload Rack (ISPR). The CIR Optics Bench portion of this document includes all components mounted on the Bench with the exception of the Combustion Chamber. Analysis of the Combustion Chamber is covered in CIR-RPT-0009. Also not covered in this document is Government Furnished Equipment (GFE). Included in this category are the EPCU, ISPR, Active Rack Isolation System (ARIS) and FDSS smoke detector. Analysis of the EPCU is the responsibility of Hamilton Sundstrand. Analysis of the FDSS smoke detector is the responsibility of Honeywell. Analyses of the ISPR and ARIS are the responsibility of Boeing.

Four of the subsystems identified above make up the Environmental Control System (ECS). They are the ATCU, WTCS, GIS and FDSS.

1.3 Organization of document.

During its lifetime, the CIR will be subjected to a variety of environments. These included the launch environment and the on-orbit environment. For much of the CIR hardware, launch is the design-driving environment. For many components subject to pressure loading during on-orbit operation, this drives the structural design. Many CIR components will be packed in foam and stowed during launch. This will isolate them from high launch loads. Therefore, crew-induced loads may be design drivers for these components. A complete set of CIR design loads is documented in FCF-PLN-0053. Because launch loads require the inclusion of random vibration loading, the derived launch loads are documented here.

In this document each subsystem will have a separate Section except for ECS subsystems. Here, a subsystem is defined as a structure that has a direct interface with the ISPR posts. For ECS subsystems, there is a section for the ATCU and a section that combines the WTCS, GIS and FDSS probe. Additional structure is required at the bottom of the rack because the standard ISPR center posts are removed for all FCF racks. It is called the Rack Center Support Structure and is included in the Section for the EPCU rails.

In each Section a matrix is provided to identify the part analyzed, the critical environment, status of analysis and minimum margins of safety (MS). The launch loads are presented as are the normal modes results on which the random vibration component of load is based. If a finite element model has been created for analysis, it will be presented. Representative stress and fracture analysis results will be given. Finally, a list of safety critical and fracture critical parts will be provided. Because of the volume of parts for some subsystems, this section will point to an appendix to this document that will contain the list.

Following the subsystem sections, a section devoted to generic types of structure such as fasteners will be presented.

2.0 DOCUMENTS

This section lists specifications, models, standards, guidelines, handbooks, and other special publications. These documents have been grouped into two categories: applicable documents and reference documents.

2.1 Order of precedence for documents.

In the event of a conflict between this document and other documents referenced herein, the requirements of this document shall apply. In the event of a conflict between this document and the contract, the contractual requirements shall take precedence over this document. All documents used, applicable or referenced, are to be the issues defined in the Configuration Management (CM) contract baseline. All document changes, issued after baseline establishment, shall be reviewed for impact on scope of work. If a change to an applicable document is determined to be effective, and contractually approved for implementation, the revision status will be updated in the CM contract baseline. The contract revision status of all applicable documents is available by accessing the CM database. Nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.2 Applicable documents.

The documents in these paragraphs are applicable to the FCF Project to the extent specified herein.

SSP 52005	Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures
SSP 57000	Pressurized Payloads Interface Requirements Document

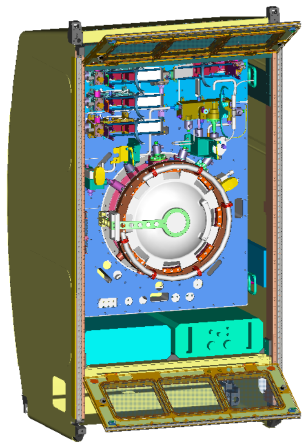
2.3 Reference documents.

The documents in this paragraph are provided only as reference material for background information and are not imposed as requirements.

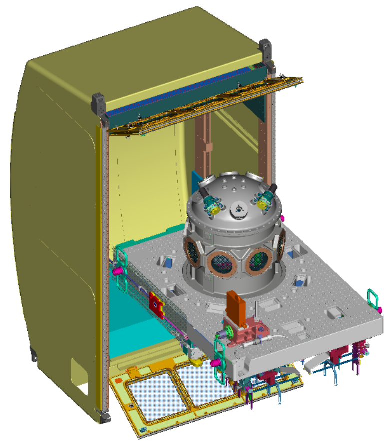
CIR-RPT-0009	CIR Design Analysis Report
FCF-PLN-0053	FCF Structural Design and Verification Plan
FCF-PLN-0029	FCF Fastener Control Plan
FCF-PLN-0030	FCF Fracture Control Plan
NASA TM-106943	Preloaded Joint Analysis Methodology for Space Flight Systems

3.0 SAFETY CRITICAL STRUCTURES

3.1 CIR structural configurations.

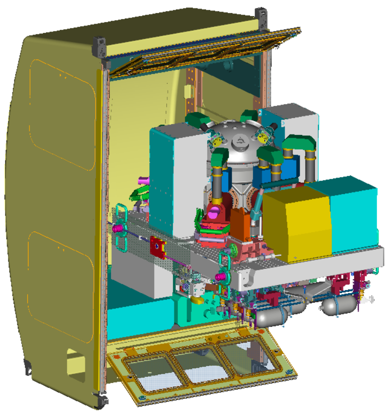


Front view of Optics Bench (Doors will be closed and secured for launch)

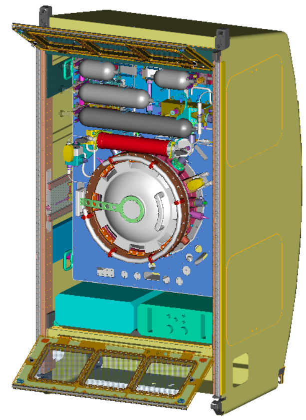


Optics bench rotated to show rear of Optics Bench (Optics Bench will be retracted and secured for launch)

FIGURE 1. CIR launch configuration



Diagnostic and imaging packages installed on-orbit



Gas bottles and filters installed on-orbit

FIGURE 2. CIR science configuration (on-orbit)

3.2 CIR structural elements and subsystems.

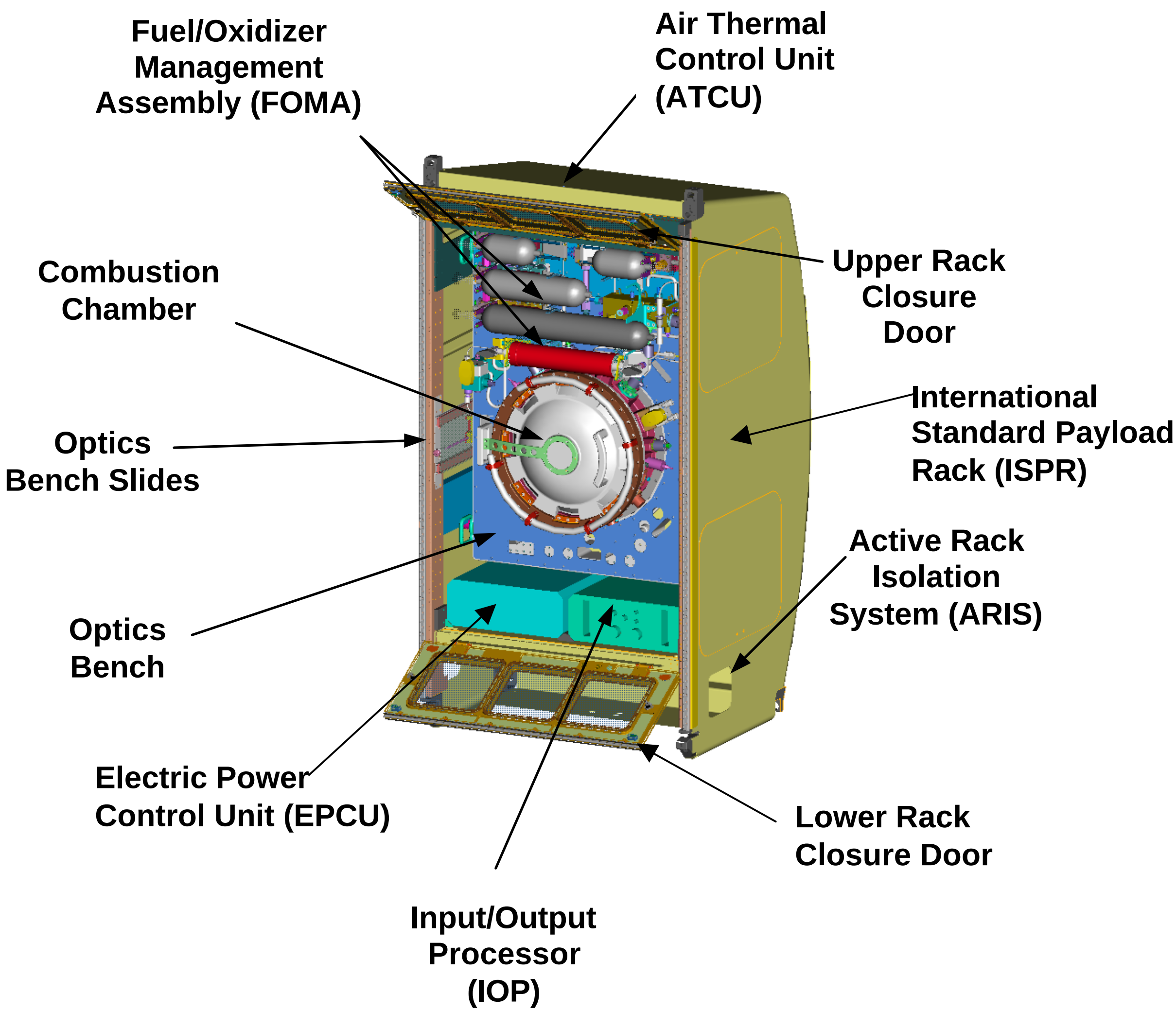
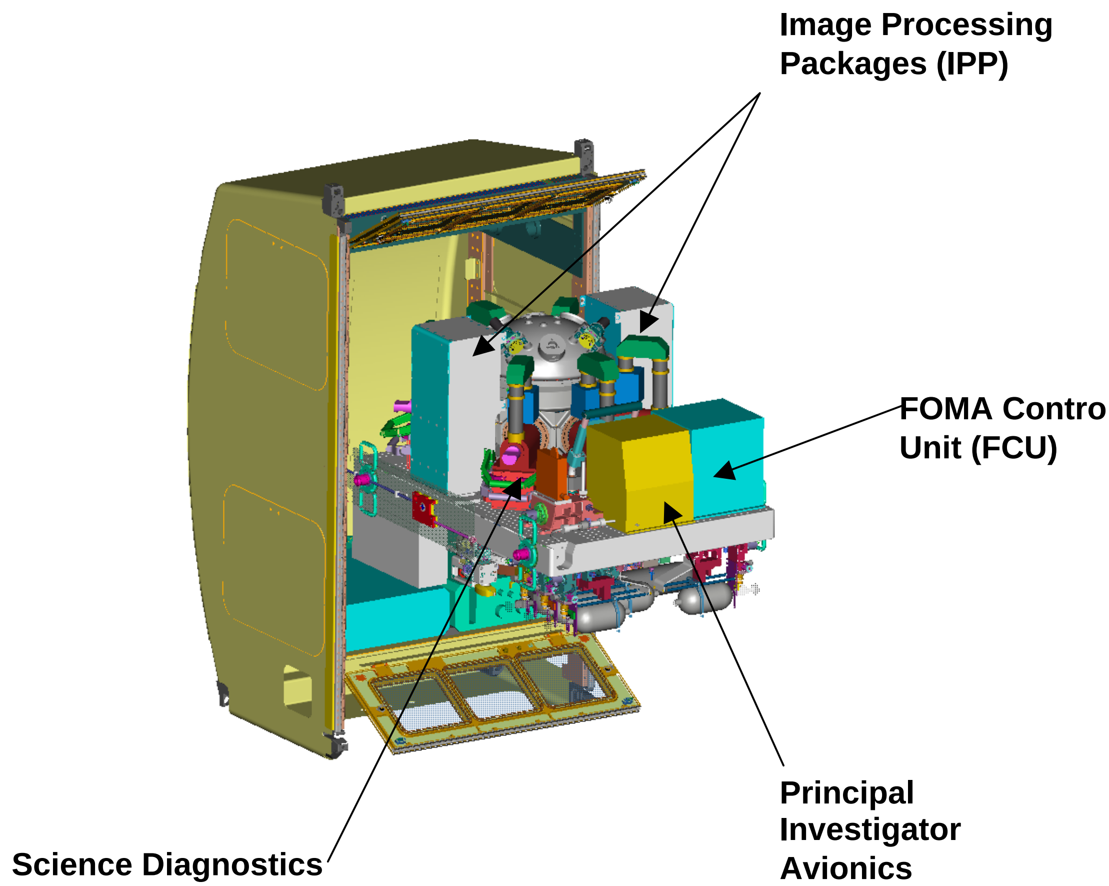


FIGURE 3. CIR elements and subsystems as viewed from front of rack



- Color Camera
- Illumination Package
- Mid Infra-Red Camera
- Low Light Level (2 Units)
- High Bit Depth Multi-Spectral
- High Frame Rate/High Resolution

FIGURE 4. CIR elements as viewed from front of rack with Optics Bench rotated

3.3 CIR load paths.

Safety critical structures are defined as those in the primary load path. Figure 1 shows the load paths for the components and subsystems that make up the Combustion Integrated Rack. For all FCF racks the standard ISPR center post is removed.

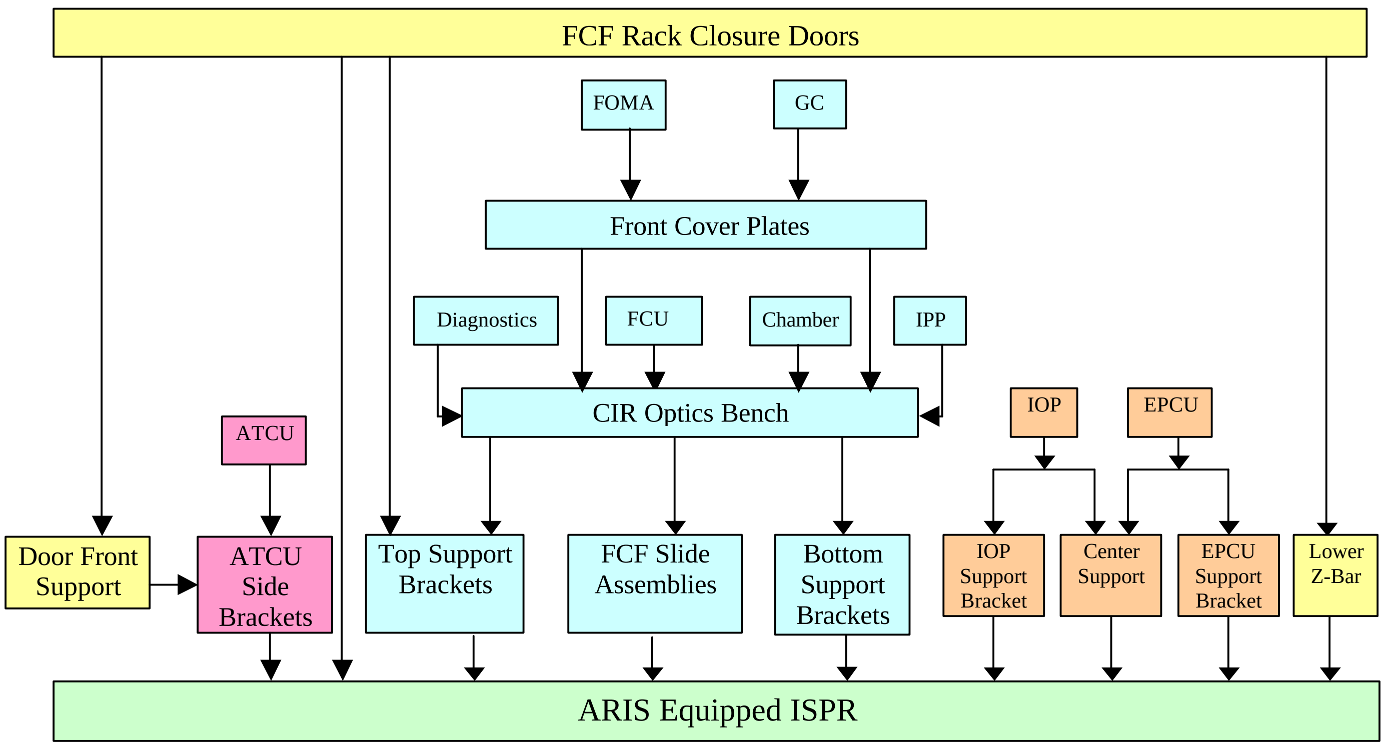


FIGURE 5. CIR load path diagram

4.0 MATERIAL PROPERTIES

The following table lists the material properties used in the assessment of CIR safety critical components and fasteners. The minimum material properties were obtained from MIL-HDBK-5 and the fastener procurement Specification FF-S-86. The materials all have an "A" rating for stress corrosion cracking per MSFC-HDBK-527 and JSC 09604. Only gases and products of combustion compatible with these materials will be allowed.

TABLE I. CIR Structural Material Properties

Material	E (ksi)	F_{ty} (ksi)	F_{cy} (ksi)	F_{tu} (ksi)	F_{cu} (ksi)	F_{su} (ksi)	F_{bu} (ksi)	Density (lbs/in^3)
6061-T651 Aluminum	9.9	35	35	42	42	27	67	0.098
7075-T7351 Aluminum	10.3	57	56	68	68	38	102	0.101
300 Stainless Steel (full hard)	26.0	125	83	174	174	95	346	0.286
300 Stainless Steel (annealed)	29.0	26	23	73	73	50	162	0.286
A-286 Stainless Steel	30.0	120	120	160	160	97	195	0.290

All materials used in the CIR are documented in CIR-LST-0051.

5.0 CIR OPTICS BENCH

The Optics Bench is the major structure in the CIR. It has many components mounted on it for Shuttle launch and many more are added once on-orbit for the conduct of combustion experiments. It is also used to duct cooling air from the ATCU to components requiring cooling.

5.1 Analysis matrix.

Table II presents the CIR Optics Bench assembly stress analysis matrix.

TABLE II. CIR Optics Bench assembly stress analysis matrix

Name of Component	Critical Design Environment	Status of Analysis	Minimum MS
Optics Bench (OB) Structure Rib	Launch	Complete	1.09 yield 0.57 ultimate
OB Cover Plates	Launch	Complete	1.92 yield 1.19 ultimate
OB to ISPR Upper Attach Brackets	Launch	Complete	0.50 yield 0.11 ultimate
OB to ISPR Lower Attach Brackets	Launch	Complete	0.65 yield 0.21 ultimate
FOMA Gas Supply Manifold	Pressure	Complete	Large
FOMA Exhaust Manifold	Pressure	Complete	Very Large
FOMA Vent Manifold	Pressure	Complete	Very Large
FOMA Manual Valve Manifold	Pressure		
FOMA Pump	Pressure		
GC Gas Supply Manifold	Pressure		
GC Instrumentation Package	Crew-induced		
FOMA Control Unit	Crew-induced		
IPP	Crew-induced		
FOMA Gas Bottle Attachment	Crew-induced		
Adsorber Cartridge Attachment	Crew-induced		
Diagnostic Instrument	Crew-induced		
Illumination Package	Crew-induced		
GC Gas Bottle Attachment	Crew-induced		

5.2 Design loads.

Launch loads for preliminary design are derived by combining quasistatic load factors with random vibration loads. Quasistatic loads are provided by the Space Station Program in SSP

57000. Random vibration load factors are based on the natural frequencies of the subsystem and the random vibration environment provided by the Program in SSP 57000. Random vibration load factors are conservatively calculated using Miles' relationship. For the CIR Optics Bench, a mass weighted approach was used. Table III presents the modal data, while Table IV presents the load factors used to assess the Optics Bench structure and its support brackets.

TABLE III. CIR Optics Bench modal analysis results

Mode	Direction*	Frequency, Hz.	Effective Mass Fraction
1	X	29.0	0.947
2	Z	53.0	.775
5	Y	114.3	.453
6	Y	142.6	.378

* ISPR coordinate system

TABLE IV. CIR Optics Bench assembly launch load factors

Case	X	Y	Z
1	+10.3/−7.3	±11.6	± 9.9
2	± 7.7	±15.1	± 9.9
3	± 7.7	±11.6	±12.0

5.3 Finite element model and analysis results.

Figure 2 presents the Optics Bench assembly finite element model. For launch analysis the Combustion Chamber is represented as a flexible beam. Components mounted to the Optics Bench are modeled as rigid masses.

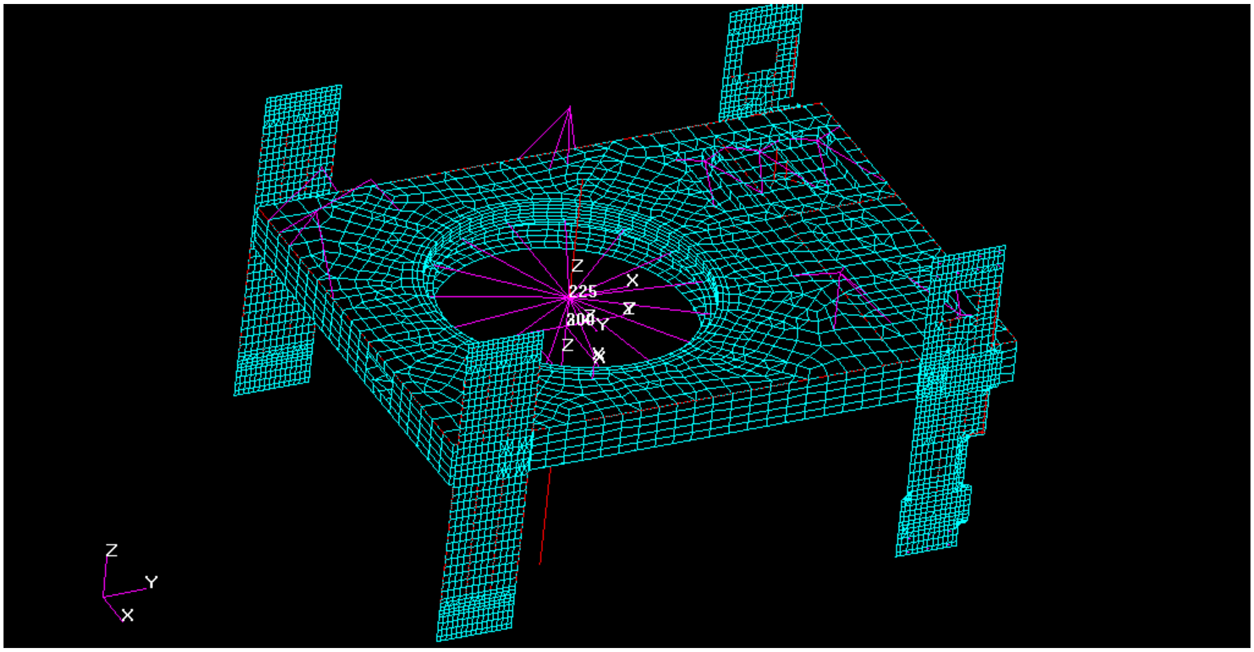


FIGURE 6. CIR Optics bench assembly finite element model

Figure 3 presents typical stress contours for one of the twelve launch load cases analyzed.

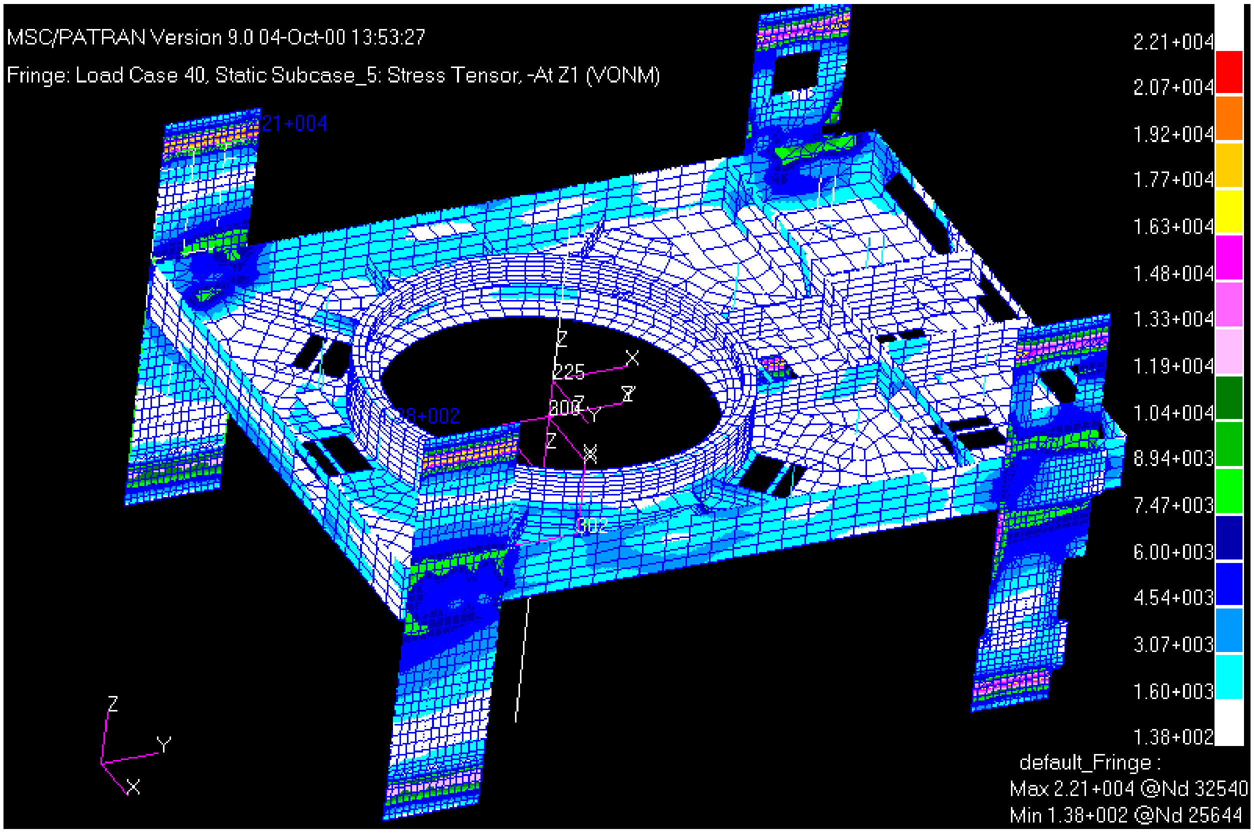


FIGURE 7. Optics bench stress contour plot (cover plates removed)

5.4 Safety critical and fracture critical parts list.

The safety critical and fractural critical parts list for the CIR Optics Bench assembly is presented in Appendix D.

6.0 COMBUSTION CHAMBER

The CIR Combustion Chamber analysis was conducted prior to the start of the MRDOC Project. It was documented in the CIR Design Analysis Report, CIR-RPT-0009. When the analysis is updated to reflect changes to the design since the earlier analysis, it will be documented here.

7.0 DEPLOYMENT SLIDES

The Deployment Slides provide the mechanism necessary to translate the Optics Bench out of the rack and rotate it to provide access to components on the back of the Bench.

7.1 Analysis matrix.

The Deployment Slides are designed to support the Optics Bench while on the ground without the use of ground support equipment (GSE), and on-orbit for crew induced and re-boost loads. The Slides are isolated from any significant loading during Shuttle launch and landing because of the structural support provided by the Optics Bench upper and lower attachment brackets. Table V presents the analysis matrix for the Slides.

TABLE V. Deployment Slides stress analysis matrix

Load Case	Optics Bench Location	Load	Optics Bench Position	Minimum MS
1	Extended	1 g	Horizontal	0.02 yield 0.08 ultimate
2	Retracted	1 g	Normal operation	0.09 yield 0.68 ultimate
3	Extended	0.2 g re-boost	Horizontal	0.48 yield 1.03 ultimate
4	Retracted	0.2 g re-boost	Normal operating	5.63 yield 5.35 ultimate
5	Extended	125 lb. kick load	Horizontal or vertical	1.91 yield 2.95 ultimate

Safety factors:

Ground (1 g) – Yield = 2.0; Ultimate = 3.0
On-orbit – Yield = 1.25; Ultimate = 2.0

7.2 Finite element model stress contour plot

Figure 4 presents stress contours for the slides in the deployed position.

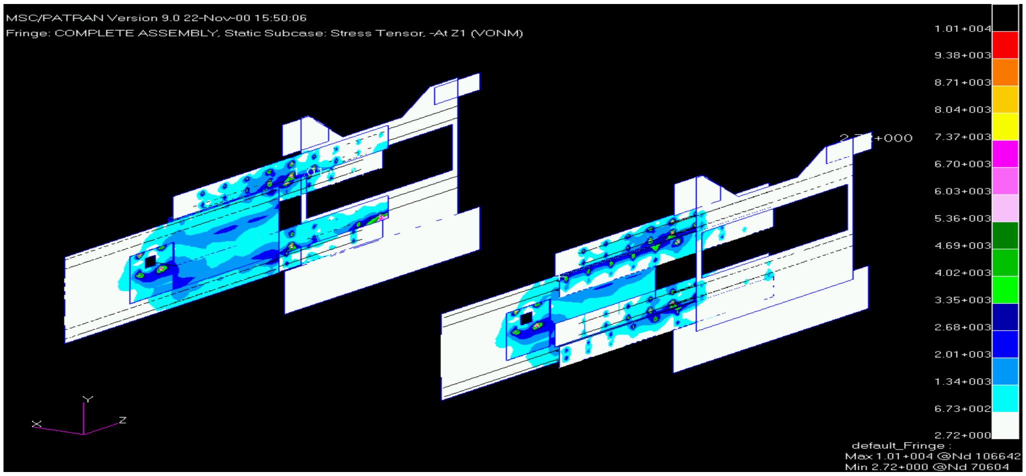


FIGURE 8. Deployment Slides stress contour plot

8.0 AIR THERMAL CONTROL UNIT (ATCU)

The ATCU houses the heat exchanger, fans, electronics and ducting necessary to provide cooling to heat generating components in FCF racks.

8.1 Analysis matrix.

TABLE VI. ATCU assembly stress analysis matrix

Name of Component	Critical Design Environment	Status of Analysis	Minimum MS
Support Bracket	Launch	Complete	1.18 yield 0.65 ultimate
Front Panel	Launch	Complete	0.68 yield 0.26 ultimate
Rear cross beam	Launch	Complete	0.78 yield 0.34 ultimate
Cross beam	Launch	Complete	0.53 yield 0.15 ultimate
Mounting bracket	Launch	Complete	0.93 yield 0.46 ultimate

8.2 Design loads.

TABLE VII. ATCU modal analysis results

Mode	Direction*	Frequency, Hz.	Effective Mass Fraction
2	Y	36.0	0.520
3	X	52.9	.909
5	Z	92.8	.414
7	Z	141.8	.279

* ISPR coordinate system

TABLE VIII. ATCU launch load factors

Case	X	Y	Z
1	±21.4	±11.6	± 9.9
2	± 7.7	±19.8	± 9.9
3	± 7.7	±11.6	±32.8

8.3 Finite element model and analysis results.

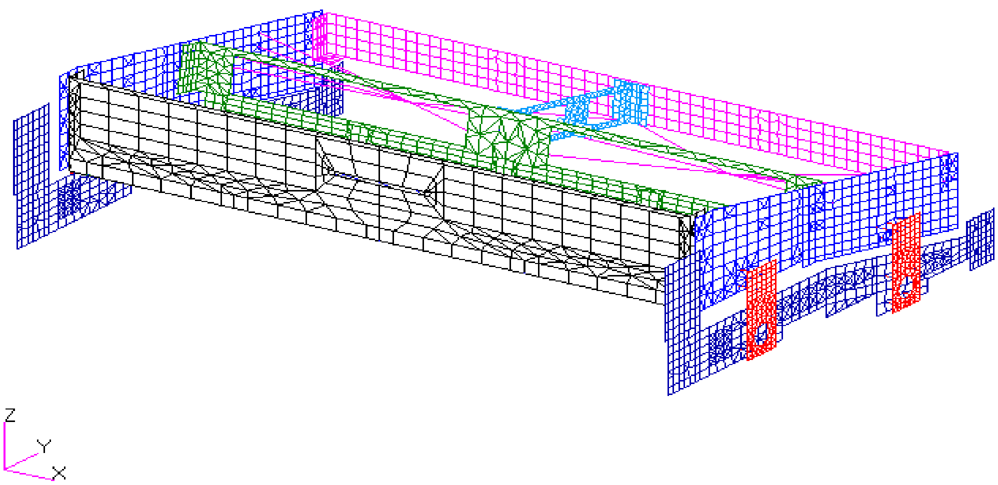


FIGURE 9. ATCU finite element model

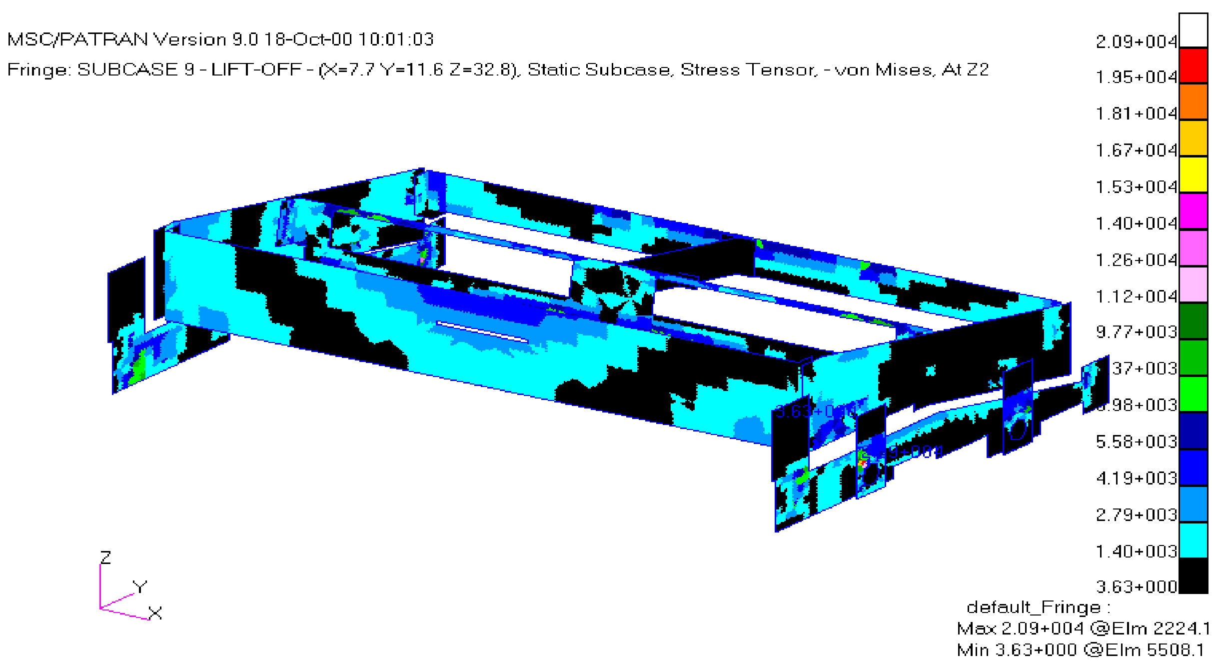


FIGURE 10. ATCU stress contour plot

8.4 Safety critical and fracture critical parts list.

The safety critical and fractural critical parts list for the ATCU assembly is presented in Appendix E.

9.0 INPUT/OUTPUT PROCESSOR (IOP)

The IOP is one of two avionics packages that are common to all FCF racks. It houses electronic components, two hard disk drives and a small cooling fan. A set of four brackets provide the load path between the IOP case and rack posts.

9.1 Analysis matrix.

TABLE IX. IOP assembly stress analysis matrix

Name of Component	Critical Design Environment	Status of Analysis	Minimum MS
IOP Case	Launch	Complete	1.6 yield 0.95 ultimate
Front Attach Bracket	Launch	Complete	2.35 yield 1.5 ultimate
Rear Attach Bracket	Launch	Complete	3.15 yield 2.1 ultimate
Bull Nose Pin	Launch	Complete	Large
Handle	Crew Induced	Complete	7.4 yield 5.3 ultimate

9.2 Design loads.

TABLE X. IOP modal analysis results

Mode No.	Direction*	Frequency, Hz.	Modal Effective Mass
2	Z	74.9	0.161
6	X	158	.583
7	X	159	.073
17	Y	197	.182
24	Y	304	.130
24	Z	304	.179

* ISPR coordinate system

TABLE XI. IOP launch load factors

Case	X	Y	Z
1	+20.3/–17.3	±11.6	± 9.9
2	± 7.7	±14.4	± 9.9
3	± 7.7	±11.6	±13.8

9.3 Finite element model and analysis results.

Figure 7 presents the IOP finite element model. The case and ISPR attachment brackets are represented in the model. Internal parts were modeled as rigid masses attached to the case.

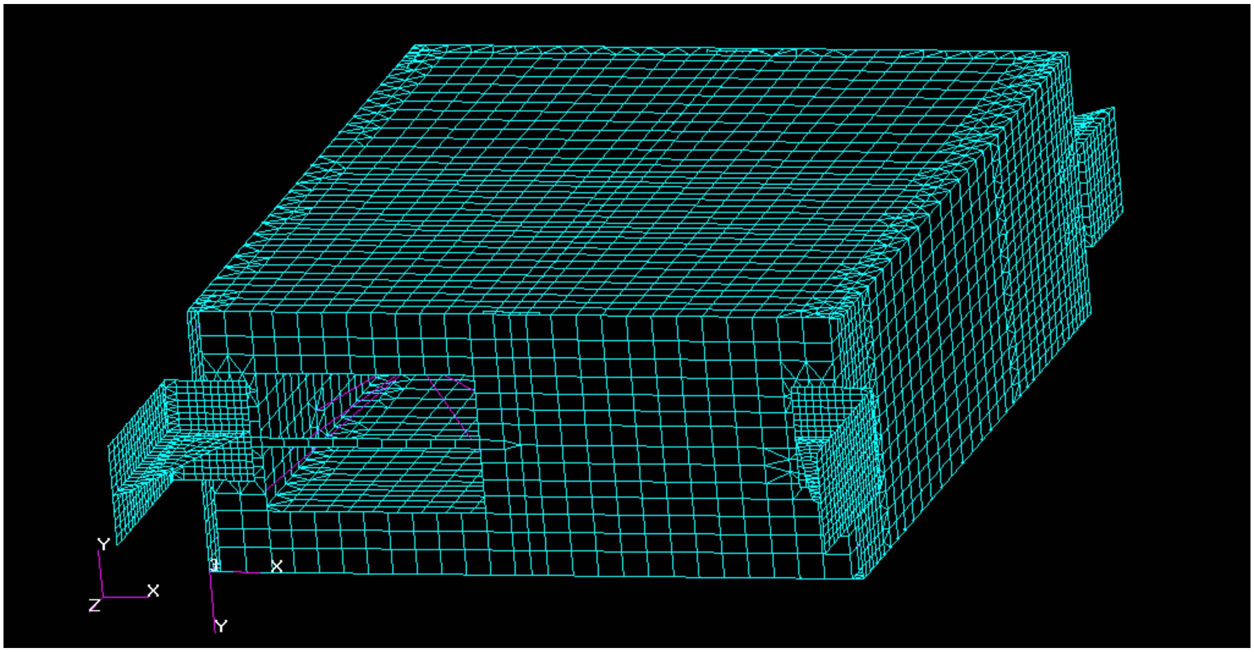


FIGURE 11. IOP finite element model

Figure 8 presents stress contours for the critical load case.

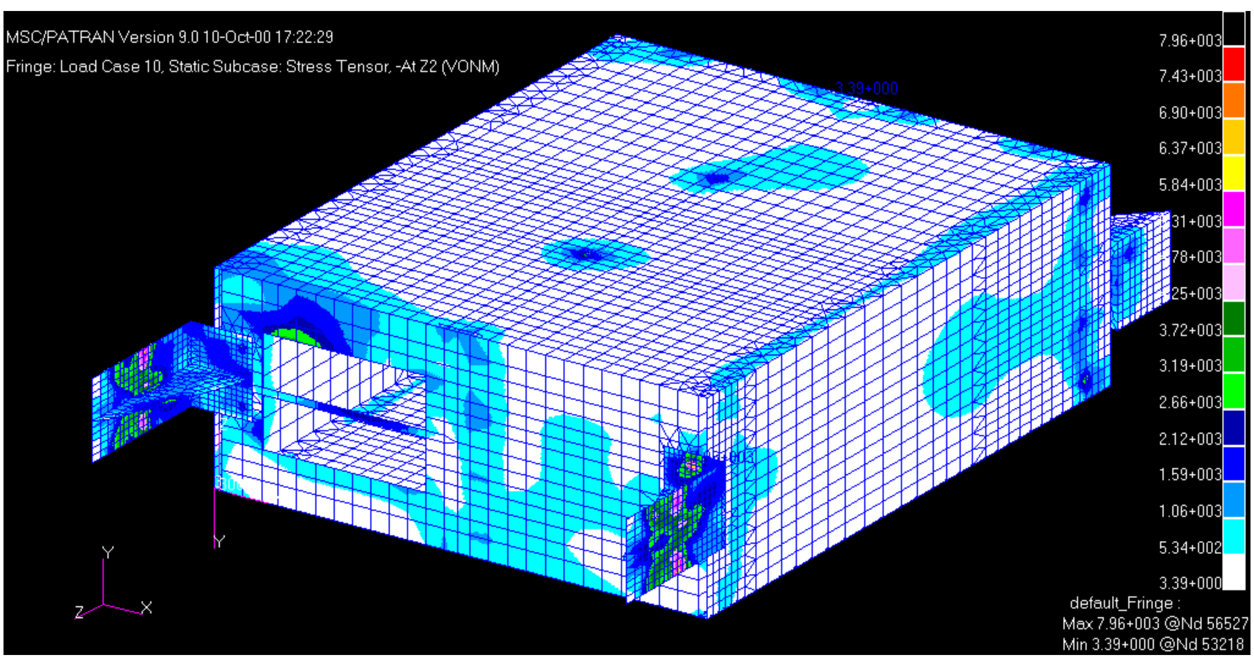


FIGURE 12. IOP stress contour plot

9.4 Safety critical and fracture critical parts list.

The safety critical and fractural critical parts list for the CIR IOP assembly is presented in Appendix F.

10.0 RACK CLOSURE DOOR (RCD)

The RCD isolates the FCF racks from the US Laboratory atmosphere. It serves to reduce the exchange of air between the rack and the Laboratory, and helps to isolate noise generated inside the racks. During Shuttle launch, the door provides a small amount of structural augmentation to the rack.

10.1 Analysis matrix.

TABLE XII. RCD assembly stress analysis matrix

Name of Component	Critical Design Environment	Status of Analysis	Minimum MS
Door Header			
Door Footer			
Upper Door Panel			
Lower Door Panel			
Adaptable Port Cover			

10.2 Design loads.

TABLE XIII. RCD modal analysis results

Mode No.	Direction*	Frequency, Hz.	Modal Effective Mass
1	Y	39.1	0.374
3	Y	62.5	.124
4	Y	80.1	.074
7	Y	116	.065
14	Y	168	.067

* ISPR coordinate system

TABLE XIV. RCD launch design load factors

Case	X	Y	Z
1	+35.7/–32.7	±11.6	± 9.9
2	± 7.7	±23.0	± 9.9
3	± 7.7	±11.6	±35.0

10.3 Finite element model and analysis results.

Figure 9 presents the Rack Closure Door finite element model.

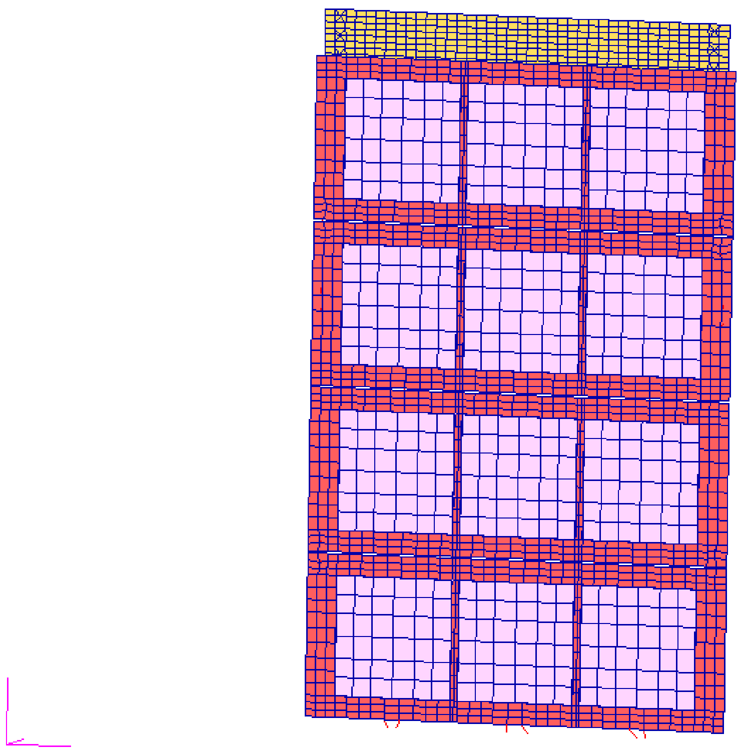


FIGURE 13. RCD finite element model

<TBD 07-01>

FIGURE 14. RCD stress contour plot

10.4 Safety critical and fracture critical parts list.

The safety critical and fractural critical parts list for the RCD assembly is presented in Appendix G.

11.0 EPCU RAILS AND RACK CENTER SUPPORT STRUCTURE

The EPCU rails and their associated brackets provide the interface for this avionics package to the rack posts. Both the IOP and EPCU span just half the rack width. Therefore, it is necessary to provide structure at the center of the rack to support these two subsystems.

11.1 Analysis matrix.

TABLE XV. EPCU rails stress analysis matrix

Name of Component	Critical Design Environment	Status of Analysis	Minimum MS
Rail	Launch		
Forward Bracket	Launch		
Rear Bracket	Launch		

11.2 Design loads.

TABLE XVI. EPCU rails modal analysis results

Mode	Direction*	Frequency, Hz.	Effective Mass Fraction
1	Y	83.4	0.276
2	X	84.9	.248
3	Y	104.8	.652
4	X	146.3	.727
5	Z	192.7	.933

* ISPR coordinate system

TABLE XVII. EPCU rails launch design load factors

Case	X	Y	Z
1	+16.1/–13.1	±11.6	± 9.9
2	± 7.7	±15.6	± 9.9
3	± 7.7	±11.6	±18.9

11.3 Finite element model and analysis results.

Figure 11 presents EPCU rails finite element model. The EPCU is represented as a rigid mass.

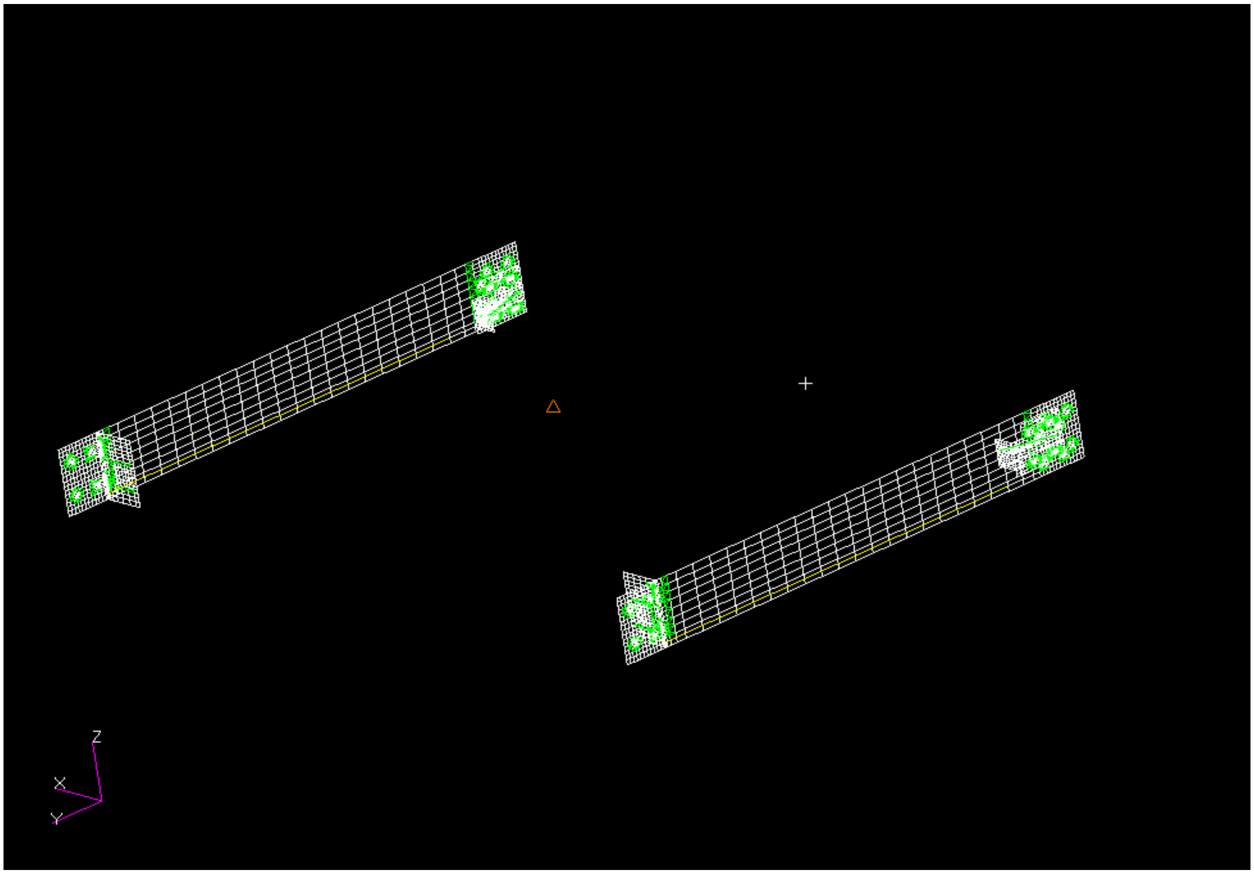


FIGURE 15. EPCU rails finite element model

Figure 12 presents stress contours for a representative load case.

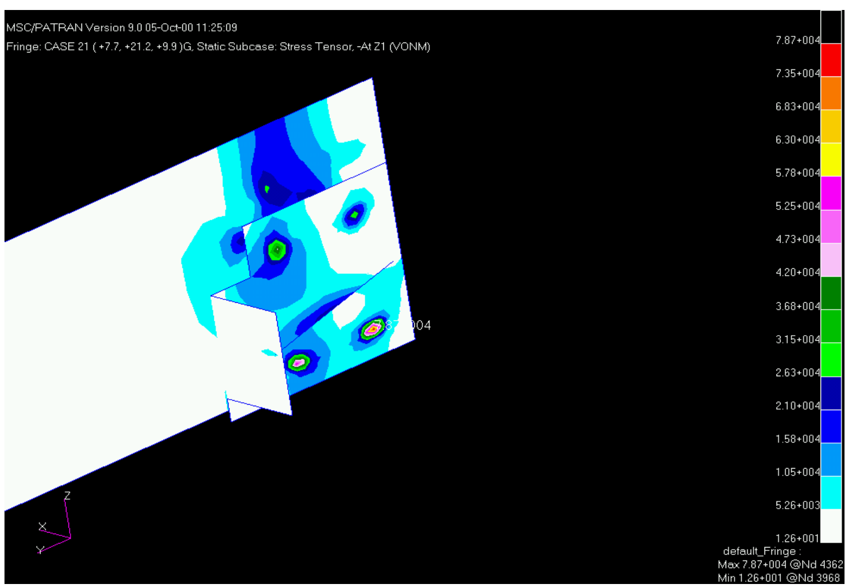


FIGURE 16. EPCU rails stress contour plot

11.4 Safety critical and fracture critical parts list.

The safety critical and fractural critical parts list for the EPCU rails is presented in Appendix H.

12.0 ENVIRONMENTAL CONTROL SYSTEM (ECS)

12.1 Analysis matrix.

This section covers the Environmental Control System (ECS) with the exception of the ATCU, which was covered in Section 5.0.

TABLE XVIII. WTCS, GIS and FDSS probe stress analysis matrix

Name of Component	Critical Design Environment	Status of Analysis	Minimum MS
WIP Cover & Stiffening Plate	Launch		
WFCA Brackets	Launch		
Accumulator Mounting Bracket	Launch		
GIS Pressure Regulator Bracket	Launch		
GIS Support Bracket	Launch		
Gas Interface Panel	Launch		
Gas Interface Panel Back Piece	Launch		
FDSS Probe Bracket	Launch		

12.2 Design loads.

Launch design loads for the WTCS, GIS and FDSS probe are based on the assumption of a natural frequency of 150 Hz. Loads based on that assumption are presented in Table XIX.

TABLE XIX. WTCS, GIS and FDSS probe launch design load factors

Case	X	Y	Z
1	+31.3/–28.3	±11.6	± 9.9
2	± 7.7	±31.3	± 9.9
3	± 7.7	±11.6	±30.7

12.3 Finite element model and analysis results.

Figure 13 presents the GIS finite element model. Structural assessment of the GIS for preliminary design is based on its natural frequency. The design goal for this structure was a minimum natural frequency of 150 Hz. Table XX presents the GIS modal analysis results.

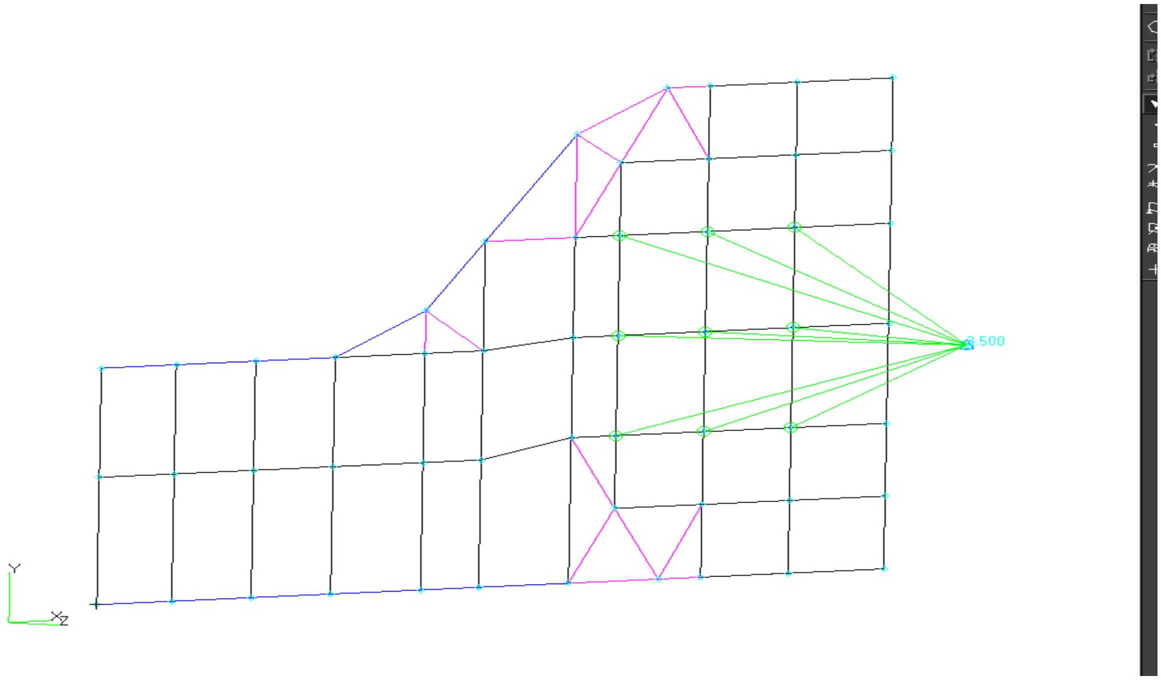


FIGURE 17. GIS finite element model

TABLE XX. GIS modal analysis results

Mode	Frequency, Hz.
1	141
2	184
3	515

12.4 Safety critical and fracture critical parts list.

The safety critical and fractural critical parts list for the WTCS, GIS and FDSS is presented in Appendix I.

13.0 FASTENERS

Preloaded fasteners are analyzed using the methodology described in NASA TM-106943.

13.1 Analysis matrix.

Table XXI present the results of CIR fastener analysis.

TABLE XXI. CIR fastener stress analysis matrix

Component	Connection	Minimum MS
Combustion Chamber	Optics Bench	0.08 yield 0.59 ultimate
FOMA Manifolds	Optics Bench	0.15 yield 0.72 ultimate
Cover Plate	Optics Bench	0.08 yield 0.17 ultimate 3.47 joint separation
Optics Bench (OB)	OB Launch Bracket	0.22 yield 0.61 ultimate 6.1 joint separation
OB Launch Bracket	Rack Post	0.14 yield 0.40 ultimate 0.27 joint separation
ATCU Side Panel	Isolation Tab	0.18 yield 0.53 ultimate 0.17 joint separation
Isolation Tab	ATCU Rack Post Bracket	0.18 yield 0.53 ultimate 0.28 joint separation
ATCU Rack Post Bracket	Rack Post	0.18 yield 0.54 ultimate 1.74 joint separation
IOP Case	IOP Front Bracket	0.22 yield 0.60 ultimate
IOP Card Cage	IOP Case	0.23 yield 0.63 ultimate
IOP Front Bracket	Rack Post	0.36 yield 0.75 ultimate 3.0 joint separation
IOP Rear Bracket	Rack Post	0.36 yield 0.76 ultimate 3.8 joint separation
EPCU Case	EPCU Front Bracket	yield ultimate joint separation

Component	Connection	Minimum MS
EPCU Case	EPCU Rear Bracket	yield ultimate joint separation
EPCU Front Bracket	EPCU Rail	yield ultimate joint separation
EPCU Rear Bracket	EPCU Rail	yield ultimate joint separation
EPCU Rail	Rack Post	yield ultimate joint separation

13.2 Analysis results.

Because of redundancy, none of the fasteners used in the CIR are fracture critical.

13.3 Safety critical parts list.

The safety critical fasteners are included in the subsystem lists found in Appendices D through I.

APPENDIX A ACRONYMS AND ABBREVIATIONS

A.1 Scope.

This appendix lists the acronyms and abbreviations used in this document.

A.2 List of acronyms and abbreviations.

ARIS	Active Rack Isolation System
ATCU	Air Thermal Control Unit
CIR	Combustion Integrated Rack
ECS	Environmental Control System
EM	Engineering Model (prototype)
EPCU	Electric Power Control Unit
FCF	Fluids and Combustion Facility
FDSS	Fire Detection and Suppression System
FOMA	Fuel Oxidizer Management Assembly
GC	Gas Chromatograph
GFE	Government Furnished Equipment
GIS	Gas Interface System
GRC	Glenn Research Center
IOP	Input/Output Processor
IPP	Image Processing Package
ISPR	International Standard Payload Rack
ISS	International Space Station
MDP	Maximum Design Pressure
MPLM	Multi-Purpose Logistics Module
MRDOC	Microgravity Research, Development and Operations Contract
MS	Margin of Safety
RCD	Rack Closure Door
RVLF	Random Vibration Load Factor
SSP	Space Station Program
STS	Space Transportation System
TBD	To Be Determined
WFCA	Water Flow Control Assembly
WIP	Water Interface Panel
WTCS	Water Thermal Control System

APPENDIX B DEFINITIONS

B.1 Scope.

This appendix defines special terminology used in this document.

B.2 List of definitions.

Fracture-Critical Part - A classification of parts that assumes that fracture or failure of the part resulting from the occurrence of a crack will result in a catastrophic hazard.

Safety-Critical Part - All structural elements in the primary load path including pressure systems, uncontained glass, and rotating machinery are safety critical.

APPENDIX C TBD'S

C.1 Scope.

This appendix lists all items in this document that need to be determined (TBD).

C.2 List of TBD's.

TABLE XXII. TBD's

TBD Number	Description	Document Paragraph
07-01	RCD stress contour plot	7.3
E-01	ATCU safety critical parts list	E.1
G-01	RCD safety critical parts list	G.1
H-01	EPCU safety critical parts list	H.1
I-01	WTCU, GIS & FDSS safety critical parts list	I.1

APPENDIX D SAFETY/FRACTURE CRITICAL PARTS LIST FOR THE CIR OPTICS BENCH

D.1 Parts list.

This appendix documents safety critical and fracture critical parts for the CIR Optics Bench Assembly. The list is incomplete.

	OPTICS BENCH ASSEMBLY SAFETY CRITICAL STRUCTURES (SCS) LIST			
SCS #	**STRUCTURE/CONNECTION**	**PART NUMBERS**	**QUANTITY**	**DISPOSITION**
1	**OPTICS PLATE ASSEMBLY**	67212MELH150	1	
	Optics Bench Frame	67212MELH151	1	NFC-1
	Chamber Cover Plate	67212MELH152	1	NFC-1
	FOMA Left Cover Plate	67212MELH153	1	NFC-1
	FOMA Center Cover Plate	67212MELH154	1	NFC-1
	FOMA Right Cover Plate	67212MELH155	1	NFC-1
	FOMA Left Cover Plate fasteners	M6 x 15 SHCS	10	NFC-1
	FOMA Right Cover Plate fasteners	M6 x 15 SHCS	10	NFC-1
	FOMA Center Cover Plate fasteners	M6 x 15 SHCS	8	NFC-1
	Chamber Cover Plate fasteners	M6 x 15 SHCS	74	NFC-1
2	**TEST CHAMBER ASSEMBLY**	67212MELH200	1	
	Rear End Cap	67212MEDH251	1	FC
	Rear End Cap/Window Section Fasteners	M6 x 1 x 20 SHCS	40	NFC-1
	Rear End Cap Center Plug	67212MEDH257	1	NFC-1
	Rear End Cap Center Plug Fasteners	67212MEDM319 (M6x1 SHCS)		
	Rear End Cap Port Plug	67212MEDH253	3	NFC-1
	Rear End Cap Port Plug Fasteners	67212MEDM318 (M5x1 SHCS)		
	Fan Mount		1	NFC-2
	Front End Cap	67212MEDH212	1	FC
	Chamber Arm (rotary)	67212MEDH213	1	NFC-1
	Chamber Arm (rotary) Fasteners	M8 x 1.25 x 12 BHSS	2	NFC-1
	Chamber Arm (rotary) Fasteners	M8 x 1.25 x 25 BHSS	2	NFC-1
	Chamber Arm (linear)	67212MEDH222	1	NFC-1
	Chamber Arm (linear) Fasteners	M4 x 0.7 x 22	8	NFC-1
	Guide Rail Fasteners	6-32 UNC-3a x 0.4375	12	NFC-1
	Window Section	67212MEDH201	1	FC
	Window Section/IRR Fasteners	M8 x 1.25 x 22 SHCS	40	NFC-1
	Window Section Assembly	67212MEDH230	8	NFC-1
	Replaceable Window	67212MEDH233	8	FC
	Interface Resource Ring (IRR)	67212MEDH211	8	FC
	Lock Ring	67212MEDH204	1	FC
	Lock Ring Fasteners			NFC-1
	Kaydon bearing	#15760001	1	FC
	Bearing Fasteners	M8 x 1.25 x 22 SHCS	36	NFC-1

FC: Fracture Critical
NFC-1: Fail Safe
NFC-2: Contained
NFC-3: Restrained
NFC-4: Low Mass

APPENDIX E SAFETY/FRACTURE CRITICAL PARTS LIST FOR THE ATCU

E.1 Parts list.

This appendix documents safety critical and fracture critical parts for the ATCU. The list is <TBD E-01>.

APPENDIX F SAFETY/FRACTURE CRITICAL PARTS LIST FOR THE IOP

F.1 Parts list.

This appendix documents safety critical and fracture critical parts for the IOP.

SCS Number	Structure or Connection	Drawing No.	Disposition
1.1	Left/Right Front IOP-to-Rack Interface Brackets	?	NFC-1
1.2	Left/Right Rear IOP-to-Rack Interface Bullnose Pins	?	NFC-1
1.3	Left/Right Rack Interface Extrusions	?	NFC-1
1.4	Left/Right Front Rack Interface Receptacles	?	NFC-1
1.5	Left/Right Rear Rack Interface Receptacles	?	NFC-1
1.6	301 to 1.4, Front IOP Plate to Front Rack Interface Receptacles Connections	?	NFC-1
1.7	303 to 1.2, Rear IOP Plate to Bullnose Pins Connections	?	NFC-1
1.8	1.2 to Rear Rack, Bullnose Pins to Rear Rack Interface Receptacles Connections	?	NFC-1
1.9	1.4 to 1.3, Front Rack Interface Receptacles to Interface Extrusions Connections	?	NFC-1
1.10	1.5 to 1.3, Rear Rack Interface Receptacles to Interface Extrusions Connections	?	NFC-1
1.11	321 to 302/305, Power Supply to IOP Center Plate/Left Plate Connection	Screw_M5_BH_10MM Long	NFC-1
1.12	341 to 302/305, Fan to IOP Center Plate/Left Plate Connections	Screw_M5_BH_10MM Long	NFC-1
1.13	333/334 to 302/304, Card cage Side Plates to IOP Center/Right Plate Connections	Screw_M5_BH_10MM Long	NFC-1
1.14	350 to 310, Hard Drive to IOP Frame Connection	Screw_M5_BH_10MM Long	NFC-1
1.15	306 to 310,Top Lid to IOP Frame Connections (M5 Screws)	Screw_M5_BH_10MM Long	NFC-1
1.16	307 to 310, Bottom Lid to IOP Frame Connections (M5 Screws)	Screw_M5_BH_10MM Long	NFC-1
1.17	306/307 to 310,Top/Bottom Lid to Front Frame Connections (M4 Screws)	Screw_M4_BH_7MM Long	NFC-1
1.18	Fiber Optic Transmitter/Receiver Mount	?	NFC-4
1.19	RTD Scandinavia Can Spider Mount	?	NFC-4
1.20	AMP 2X2 Fiber Optic Coupler Mount	?	NFC-4
1.21	Plate, Front – IOP	67212MFDB301	NFC-1
"	Threaded Insert	Keensert_M4x0.8	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
1.22	Plate, Center – IOP	67212MFDB302	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
1.23	Plate, Rear IOP	67212MFDB303	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
1.24	Plate, Right – IOP	67212MFDB304	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
1.25	Plate, Left – IOP	67212MFDB305	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
1.26	Enclosure, Top Lid	67212MFDB306	NFC-1
1.27	Cap_Scr_	M5_47-91-501-60_Pres_In	NFC-1

SCS No.	Structure or Connection	Drawing No.	Disposition
1.28	Cap_Scr_	M4_47-91-301-22_Pres_In	NFC-1
1.29	Enclosure, Bottom Lid	67212MFDB307	NFC-1
1.30	Cover, Access - Card cage	67212MFDB308	NFC-1
1.31	Cap_Scr_	M5_47-91-501-60_Pres_In	NFC-1
1.32	305 to 301, Left Plate to Front Plate Connection	Screw_M5_SH_10MM Long	NFC-1
1.33	305 to 303, Left Plate to Rear Plate Connection	Screw_M5_SH_10MM Long	NFC-1
1.34	304 to 301, Right Plate to Front Plate Connection	Screw_M5_SH_10MM Long	NFC-1
1.35	304 to 303, Right Plate to Rear Plate Connection	Screw_M5_SH_10MM Long	NFC-1
1.36	301 to 302, Front Plate to Center Plate Connection	Screw_M5_SH_10MM Long	NFC-1
1.37	303 to 302, Rear Plate to Center Plate Connection	Screw_M5_SH_10MM Long	NFC-1
1.38	Handle – IOP	67212MFDB311	NFC-4
1.39	311 to 301, Handle to Front Plate Connection	Screw_M5_BH_10MM Long	NFC-4
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-4
---	Assy – Card cage	67212MFDB320	---
1.40	321 to 322, Card cage Top Plate to Side Plates	Screw_M5_BH_10MM Long	NFC-1
1.41	321 to 322, Card cage Bottom Plate to Side Plates	Screw_M5_BH_10MM Long	NFC-1
1.42	Plate, Top & Bottom - Power Supply	67212MFDB321	NFC-1
1.43	Plate, Sides - Left and Right, Power Supply	67212MFDB322	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
1.44	Plate, Mounting NBF150 - NB150S	67212MFDB323	NFC-4
1.45	Plate, Mounting NBF50 - NB50S	67212MFDB324	NFC-4
1.46	Plate, Mounting	?	NFC-4
1.47	Lid, IOP, Bottom Air Exit Plenum	?	NFC-1
1.48	Side, Air Exit Plenum	?	NFC-1
---	Assy, Card cage	67212MFDB330	---
1.49	Plate, Front - Card cage	67212MFDB331	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
"	Threaded Insert	Keensert_KNCML25x045	NFC-1
1.50	Plate, Rear - Card cage	67212MFDB332	NFC-1
"	Threaded Insert	Keensert_KNCML_M5x0.8	NFC-1
"	Threaded Insert	Keensert_KNCML25x045	NFC-1
1.51	Plate, Side - Card cage	67212MFDB333	NFC-1
1.52	Plate, Side - Card cage	67212MFDB334	NFC-1
1.53	Angle, Support - Card cage	67212MFDB335	NFC-1
1.54	333/334 to 331, Card cage Side Plates to Front Plate Connection	Screw_M5_BH_10MM Long	NFC-1
1.55	333/334 to 332, Card cage Side Plates to Rear Plate Connection	Screw_M5_BH_10MM Long	NFC-1
1.56	335 to 331/332, Card cage Support Angles to Front and Rear Plate Connections	Screw_M5_BH_10MM Long	NFC-1
1.57	DC Fan	EBM-PAPST_4312-NGH	NFC-1
1.58	Plate, Mounting - DC Fan	67212MFDB341	NFC-1
"	Threaded Insert	Keensert KNCL0632L	NFC-1
1.59	1.57 to 341, Fan to Mounting Plate Connection	Screw_M3x12-7MM	NFC-1
1.60	Lower Right Bracket	67212MFDB351	NFC-1
1.61	Upper Right Bracket	67212MFDB352	NFC-1
1.62	Upper Left Bracket	67212MFDB353	NFC-1
1.63	Lower Left Bracket	67212MFDB354	NFC-1

SCS No.	Structure or Connection	Drawing No.	Disposition
1.64	Bracket Cover, Left - Upper & Lower	67212MFDB355	NFC-1
1.65	Bracket Cover, Upper Right	67212MFDB356	NFC-1
1.66	Top Cover, Pt. 1	67212MFDB357	NFC-1
1.67	Mounting Bracket - Pt. 2	67212MFDB358	NFC-1
1.68	Plate - Bottom Air Deflector	67212MFDB359	NFC-1
1.69	NBF150 EMI Filter	Commercial Part	NFC-4
1.70	NBF50 EMI Filter	Commercial Part	NFC-4
1.71	Disk Drive	Commercial Part	NFC-1
1.72	Screw	UNC0632_325_IN	NFC-1
1.73	Rivet	MS20470_AD3_7	NFC-1

Disposition Designations
FC -- Fracture Critical
LRFP -- Low Risk Fracture Part
NFC-1 -- Fail-Safe
NFC-2 -- Contained
NFC-3 -- Restrained
NFC-4 -- Low Mass

Note: None of the IOP parts are fracture-critical.

APPENDIX G SAFETY/FRACTURE CRITICAL PARTS LIST FOR THE RCD

G.1 Parts list.

This appendix documents safety critical and fracture critical parts for the RCD. The list is <TBD G-01>.

APPENDIX H SAFETY/FRACTURE CRITICAL PARTS LIST FOR THE EPCU BRACKETS AND RACK CENTER SUPPORT STRUCTURE

H.1 Parts list.

This appendix documents safety critical and fracture critical parts for the EPCU Rails. The list is <TBD H-01>.

APPENDIX I SAFETY/FRACTURE CRITICAL PARTS LIST FOR THE WTCU/GIS/FDSS

I.1 Parts list.

This appendix documents safety critical and fracture critical parts for the WTCU, GIS and FDSS. The list is <TBD I-01>.